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THE POCAHONTAS EXPLOSION.

BY ANDREW ROY.

On Thursday, March 13th, 1884, an explosion occurred in the Pocahontas East Mine, a mine opened in the Blue Stone Flat Top Coal Field, in Tazewell county, Virginia, by which all who were in the mine at the time, 114 in number, were killed. No accident in the history of coal mining in America ever equaled this catastrophe in loss of life.

This accident, by reason of its appalling character, and the theory that coal-dust had caused the explosion, has attracted unusual attention among practical and scientific miners.

The mine was a drift or level free opening and was considered by the officers in charge to be not only free from the presence of fire-damp, but even from the possibility of generating gas. When therefore the explosion occurred, the superintendent insisted that fine coal-dust, held in the air of the mine by mechanical suspension, had exploded, producing the catastrophe.

Shortly after the accident, the South-West Virginia Improvement Company, which owned and operated the mine, requested the President of American Institute of Mining Engineers to appoint a committee of expert members of that association to investigate the cause of the explosion. The committee, consisting of three members of the American Institute, made a thorough examination of the mine before operations were resumed. They were not satisfied as to the cause of the explosion, finding no trace of fire-damp in the workings, and while not certain whether the mine made fire-damp or not, concluded, after stating the condition which led to the catastrophe, "that the explosion was due either to coal-dust alone, or to coal-dust quickened by an admixture of fire-damp too slight for detection by ordinary means." The report of this committee was read before the Chicago meeting of the American Institute of Mining Engineers, held in May, 1884, and forms part of the transactions of the Institute.

On the 9th of November last I visited the mine and examined the workings several times during a ten days' sojourn in Tazewell County. The coal is of sub-conglomerate age, belonging to the series of sub-conglomerate coals found along the southeastern outcrops of the Great Appalachian Coal Field. This seam is known as No. 3 of the series, and lies about 100 feet above the upper surface of the brown shale. The coal ranges from 9 to 11 feet in thickness and is semi-bituminous in character, resembling the coal of the Frosthope, Maryland, Field. Only 8 feet of the bed is mined in working forward, 2 feet or more of top coal being left unwrought to form the roof of the mine. In drawing pillars, this roof-coal is sought to be recovered. There is a foot or two of brittle shaly rock above the coal; upon this rests a massive sandstone resembling the sandstone overlying the great thick coal of the Hocking Valley of Ohio.

The main gallery of the mine, which was double, was driven due north on the rise of the strata, which pitches at the rate of 4 feet to the hundred. Double branch entries were opened on both sides of the main gallery at intervals, ranging from 400 to 1,200 feet. From the first east entry two double entries were driven north on lines parallel with the main gallery. These entries, known as No. 2 North of No. 1 East and No. 3 North of No. 1 East, had rooms opened on both sides, which were driven east and west along the line of strike of the strata. Two additional east entries called No. 2

East and No. 3 East, were opened off the Main North entry. The workings between the Main North and the Second North of the 1st East were therefore divided into blocks or panels. On the west side of the main gallery, there were two entries, the 1st West and the 2nd West, from which the rooms were worked to the north. Along the rise of the strata, but near the face of the 3rd and inner West, an entry was driven north on a line parallel with the main entry, and the rooms here opened east and west after the manner of the workings on the east side of the mine. All the entries were double and were each driven 10 feet wide, a pillar 30 feet in thickness being left between the parallels which was cut through every 100 feet for air. The rooms were started at nine feet wide, but after advancing a few yards were opened out to 21 feet; pillars fifteen feet in thickness being left between rooms, which were cut through every 100 feet.

The mine, which was opened in the fall of 1881, had not been worked over an area of more than 20 acres when the explosion occurred, about 200,000 tons of coal having been mined. With the exception of a few rooms on the 1st and 2nd West entries none of the working places of the mine had been finished up. On the 2nd West pillars were being drawn in the first ten rooms of the entry.

There were five separate openings to the mine, one on the east and three on the west of the main opening. The east opening was the intake and the extreme west one the upcast. Ventilation was produced by an 8-foot Murphy Fan, capable of moving 75,000 cubic feet of air through the galleries of the mine.

The ventilating current first traversed the southern division of the 1st East entry, thence returning by the northern division to the 3rd North of the 1st East, it was sent up the east side of this entry and brought back along the west parallel. Returning to the 2nd North the current was split, part going up each parallel. On reaching the 2nd East there was a direct course opened for the air to return down to the Main North entry, so that all the workings between the 2nd and 3rd East entries were deprived of the greater portion of the air designed for this division of the mine. This part of the workings, which was known as "Hell's Half Acre," consisted of 33 working places, besides the entries, and was the worst ventilated division of the mine.

In addition to the defective plan of ventilation existing in "Hell's Half Acre," there was gross negligence in regard to keep-

ing the trap doors of the mine shut. For some days before, and at the time of the explosion, the doors for guiding and directing the main current of air were propped wide open, so that the column of air which entered the mine, instead of being forced forward to the interior, where the miners were at work, passed directly to the fan entry and was delivered to day. The air in the workings were thick and vapid.

For more than a year before the explosion there were frequent warnings that the mine was generating explosive gas.

In January, 1883, an explosion occurred in the 1st East entry. The gas having kindled from a shot, the flame of the burning air rolled along the roof of the entry for a hundred feet, raising a cloud of dust and alarming the miners, who could not comprehend its meaning.

During the fall of 1883, George Brittan was severely burned by an explosion. The gas which kindled from a shot, rolled in a vast flame through the break-through in which he stood, thirty-five feet from the face of the room.

Two Hungarian miners, after firing a shot, went outside, and, on returning to their room, an hour afterwards the fire damp caught from one of their lamps, causing a slight explosion.

Other slight explosions have occurred.

Notwithstanding these admonitions, the Superintendent and mine boss ridiculed the idea of their being explosive gas generated in the mine. They entertained the too common but erroneous view that no drift mine generates explosive gas. Neither of them had ever seen fire-damp in their lives. The mine boss proved by his testimony before the coroner's inquest that he did not know fire-damp from black-damp. And few, if any, of the miners, the majority of whom were Virginian darkies and Hungarian emigrants, were better informed in regard to gas.

The mine was run day and night. The explosion occurred at half past one in the morning, the night shift having been at work for over six hours. At the time of the accident the weather was soft and wet, and had been so for some days. The mine boss informed me that there were five distinct explosions; others who heard the blast say that there were but three, occurring within two or three minutes, and that each blast shook the earth and was louder than the most terrific thunderbolt.

When I examined the mine, eight months after the catastro-

phe, the lines of direction of the rolling volumes of burning air could still be seen. The roof and pillars were charred by the intense heat of the inflamed atmosphere. The first explosion, which evidently originated at or near the head of the workings in "Hell's Half Acre," split into two columns, one stream of flame rolling southward through the working places in "Hell's Half Acre," and the other rolling westward along the 3rd East entry. At the 2nd East, at the foot of "Hell's Half Acre," the burning gas again divided, one column flying through the 2nd East and the other traveling to and along the 1st East to the 3rd North, the lurid flames rolling from roof to pavement, scorching every living creature within their reach to death. On the west side of the Main North entry, few, if any, of the miners were burned, as the inflamed gas did not penetrate this part of the mine. At one point, near the face of the 2nd North off the 3rd West, seventeen colored men were found dead in the heap, from the effects of after-damp. They had heard the noise of the blast and evidently had all run together in terror, doubtless feeling that the angel Gabriel had come and blown the last trumpet. Had they run outside, on hearing the explosions, every one of them might have been saved. In this part of the mine a Hungarian was found dead, with his undermining pick in his hand, having died from the effects of the overcharged atmosphere; others were lying flat on the floor of the mine with their faces downward and their arms stretched out as though they had fallen while running.

No effort was made after the explosion for the rescue of those who escaped the burning air. The mine boss, losing all self-control, retired to his bed from which he did not rise for two weeks, having been paralyzed through fear and remorse over the awful catastrophe.

A few days after the explosion, the mine, by the advice of an experienced mining engineer from the Midlothian mines near Richmond, was hermetically sealed and flooded with water—the coal having caught fire from the burning air. Four weeks elapsed before the workings were re-entered and the bodies of the dead miners recovered. Not a trace of inflammable gas was found in the workings. This fact, of not unusual occurrence in drift mine explosions, doubtless influenced the Committee of the American Institute of Mining Engineers in reaching the conclusion that the explosion was due either to dust alone or to dust quickened by an

admixture of fire-damp too slight for detection by ordinary means.

The explosion was, however, caused by fire-damp, although the power and extent of the blast must have been intensified by the dry coal-dust raised in the air by the disturbance. The several explosions which followed each other in quick succession show that gas had accumulated in separate divisions of the mine. The rooms in "Hell's Half Acre" and in No. 3 North off the 1st East were doubtless the scenes of the second and third explosions.

A mine that made fire-damp so slowly that it required weeks and months to accumulate an explosive compound of air and gas from the freshly cut faces of the coal, the workings meanwhile never resting day or night, would as a matter of course show no signs of inflammable gas on the safety lamp, in lying idle for a single month.

Every mine makes fire-damp, in a greater or less degree, from the freshly cut working faces, although in many mines an explosive mixture is never formed at once. But the Pocahontas Mine was not one of this kind, for the flashings of unusual extent, which preceded the great explosions, were fire-damp explosions, and nothing else. It is marvelous that the Committee of the American Institute of Mining Engineers, in the face of the burning of George Brittan, and "two instances in which a body of flame has been described as flashing back sixty to one hundred feet from the head of an entry, following the firing of a shot," were unable to comprehend that these were fire-damp explosions. They were as surely slight explosions of fire-damp as that the mine exploded on the 13th of March, 1884. Had coal-dust alone, or dust quickened by an admixture of fire-damp too small to be detected by ordinary means caused the explosion, the noise of the burning dust would have resembled that of a burning prairie as the flames rolled through the galleries of the mine, instead of the loud and heavy instantaneous reports described by those who heard the several blasts. Moreover, it is conceded on all sides that under no circumstances can dust be fired in a mine, if indeed it can be fired at all, except by the disturbance caused by blown out shot; and it is well understood that this explosion was *not* caused by a blown out shot. The escape of fire-damp, which is governed by the varying pressure of the atmosphere, was no doubt unusually great for some time preceding the explosion. The state of the weather at the date of the catastrophe favors this view of the case.

Instead of dust alone or dust mixed with fire-damp too slight to be detected by ordinary means causing the explosion, it was a genuine fire-damp accident, intensified by coal-dust.

An explosion of similar character occurred in the Robbins Mine in Columbiana county, Ohio, on the 10th of February, 1881, except that there was no dry fine coal-dust in the mine. The colliery was comparatively new, less than ten acres having been excavated, and the opening was above water level. Until the morning of the explosion gas had never been seen in serious volume, although the air at times was very bad, owing to neglect of the trap doors—so bad in fact, that many of the miners could scarcely keep their lamps burning. A sudden accumulation of gas occurred during a change from extremely cold to damp and rainy weather. On the morning of the 9th of February there was just a shade of gas in entries Nos. 2 and 3, in the safety lamp; there were 30 yards in one of these entries and 35 in the other. The next morning the mine was made a hopeless wreck by the explosion, the whole of the ventilating arrangements having been blown away. Two weeks elapsed before the workings were re-entered, when not a trace of gas was found in any part of the workings, although the ventilation had not been restored. Gas was never afterwards seen in the mine, not that it was not given off, but that the ventilation was so improved that it could not accumulate to the explosive point.

The Pocahontas catastrophe is the first case in the history of American coal mining in which the *coal-dust theory* has been advanced to account for an explosion. This subject has, however, been discussed in England and on the Continent, by the ablest living mining engineers, for several years. Numerous experiments have been made with coal-dust, by mining engineers, by mining institutes, and by government commissions, and the results thus far are alike unsatisfactory and contradictory. As early as 1845, Messrs. Lyell and Faraday called attention to the fact that fire-damp was not the only force in colliery explosions where fine dry coal-dust existed in copious volumes. In France, M. M. Sorich, 1855; Verpillieux, in 1864; Vital and Touraeni, in 1875, as well as other French mining engineers, made experiments with the fine dry coal-dust of mines to determine its influence in explosions. An elaborate series of experiments, the most thorough ever undertaken in England, were made with coal-dust by a committee of the

Chesterfield and Derbyshire Institute of Mining Engineers in 1879. This committee, as a result of its experiments, came to the unanimous conclusion that while coal-dust can be inflamed, under especially arranged conditions, no explosion, only ignition of the dust, results, unless fire-damp is present in the air, and that the finest, freshest, and most highly inflammable coal-dust floating in the air of mines in which no fire-damp is present can not be ignited by any direct action of a blown out shot. In air, however, charged with a percentage of fire-damp, as low as from one-half to three per cent, which can not be detected by ordinary safety lamp the indications are that a heavily charged blown out shot might raise a cloud of dust which would form an explosive compound.

The researches of Mr. W. Galloway, late Government Inspector of Mines, on the influence of coal-dust in colliery explosions, published in the proceedings of the Royal Society, have attracted the earnest attention of mining engineers in every coal producing country in the world. Mr. Galloway's earlier experiments showed that coal-dust was not inflammable at ordinary pressure, but that a mixture of gas in the proportion of one volume of fire-damp to one hundred and twelve of air would cause explosion. In a subsequent communication to the Royal Society, read in June, 1881, after describing a new series of experiments, on a larger scale than those formerly made, he states that the flame of coal-dust appears to be self-supporting in pure air, but can not get much beyond the point to which the more energetic action of the fire-damp explosion has extended. In his fourth paper, read before the Royal Society in May, 1884, Mr. Galloway states that since his former papers on the subject of coal-dust were read, he has investigated the cause of several great accidents, and is of the opinion that coal-dust alone is capable of producing as fatal and destructive catastrophes as the most violent fire-damp explosions; that fire-damp is not necessary in any quantity to cause explosion in a dry and dusty mine—a shot which blows out its tamping, raising and inflaming a cloud of dust, being in his judgment, sufficient. Shots of this kind, he insists, have been the cause of great explosions in the mines of England, in which there could be nothing but pure air—in the intake airways of the mine, for example. The same facts are, however, quite differently explained by other mining engineers.

The governments of Great Britain, France and Prussia have in recent years created special commissions to inquire into the

cause of mining accidents, each of which has made coal-dust and its influence in colliery explosions the subject of searching investigation.

The French Commission ascertained that the tendency of coal-dust to explode, depends upon the amount of volatile matter in the coal; that the quantity of fine dust, required to be mixed with the air of mines to cause explosion, can only be raised by violent mechanical action; that the ignition of dust can be caused only by very strong flames; that flame is transmitted very slowly in air loaded with dust. The commission concluded that coal-dust alone could only give rise to local explosions of very limited extent.

The English Commission presented a preliminary report in 1881, and is still engaged upon their final report. The report of 1881 is brief, but the evidence very voluminous. The most experienced practiced miners in the United Kingdom were almost unanimous in the opinion that coal-dust is not of itself inflammable to any serious extent, and no instances had ever come under their observation of explosion being caused by coal-dust alone. At the same time the majority concurred in the view that while coal-dust could not itself cause an explosion it did intensify the power and extent of the blast.

Experiments made by the German Fire-damp Commission, on the other hand, seemed to favor the researches of Mr. Galloway and the English Mining Commission. At the request of one of the members of the German Commission, the scientific technical committee of the Commission made a series of experiments in October, 1884, under circumstances more closely resembling actual mining conditions than any that had previously been undertaken. A number of small cast-iron mortar guns, whose bore holes were no larger than the ordinary drill hole of a miner, were taken into an old stone drift 167 feet in length. The guns, which were protected by a heavy block of masonry, were fired by electricity, the result being watched through small but thick glass windows inserted in cast-iron frames. The guns were charged with eight inches of powder, making a cartridge one foot in length; they were then tamped with clay or fine coal, nineteen and a half inches. The length of flame of a gun tamped with clay was ten feet, with small coal tamping, twenty-six feet. The floor was then covered for one hundred and thirty-one feet in length, with a layer of fine coal-dust of poor quality to a depth of one and a half inches. A gun

fired with clay tamping produced a flame eighteen feet in length; with small coal-dust tamping the flame increased to thirty-one feet. When coal-dust was laid on the floor, from the Pluto Mine, in Westphalia, which has been the scene of several explosions, a heavy explosion followed the discharge of the gun, the flame extending a length of one hundred and ninety feet—twenty-three feet beyond the mouth of the adit.

Experiments with fire-damp were also made, the gas having been taken from a mine three hundred and ninety-four feet below the surface; five per cent. of gas, mixed with air, produced a flame thirty-six feet long. A layer of coal-dust, taken from the Pluto Mine, was then sprinkled on the floor for sixty-five feet. A loud explosion followed the firing of the gun and the flame reached out a hundred and seventy-one feet.

On the 6th of January last, Mr. Thomas Cole, the intelligent mine boss of the Kelly Coal Company, near Glen Roy, in Jackson county, O., made an experiment with coal-dust in one of the dry headings of the Kelly Mine. He collected about fifty pounds of coal drillings, made with the miners' patent auger, and dried them at the ventilating furnace of the mine. A hole three and a half feet in depth was drilled in the solid coal, which was charged with fourteen inches of powder, the tamping being fine dry coal-dust. The floor of the heading was strewn with coal-dust one and a half inches in thickness, from in front of the hole up to its mouth. Mr. Charles R. John, the Superintendent of the mine, Mr. Cole and myself watched the result. The flame of the blown out shot did not reach back further than three or four feet, as near as we could judge, and not an ounce of coal-dust caught fire. Mr. John then collected half a keg full of the dust and fired his pistol into it, holding the muzzle at the mouth of the keg, but no ignition resulted.

On the 14th of January I took a sample of this dust, together with several samples of the dust of the Pocahontas Mine, to Prof. N. W. Lord, of the School of Mines in the State University of Ohio. Prof. Lord had samples of several Ohio coals and made a series of experiments with each. The apparatus used was a pipe seven inches in diameter and two and a half feet long, which was set on end, air holes being made at the bottom. A light was kept burning at the bottom of the pipe, which raised the temperature of the air 120 degrees, Fahrenheit's scale. Pulverized coal-dust from

the Coshocton coal in Coshocton county, Ohio, which contains from forty to forty-four per cent. of volatile combustible matter, was placed in a sieve containing eighty apertures to the square inch and shaken over the pipe, the dust falling in a thick cloud upon the light. The dust immediately inflamed and filled the pipe.

Dust from the Kelly Mine, in Jackson county, where the experiment was made by Mr. Cole, was then tried, but flame could not be produced, though the light of the lamp at the bottom of the pipe became lengthened to eight or nine inches. The dust was then thoroughly dried, and was warmed to a temperature of 60 degrees, and tried again with the same result.

The experiment was then made with dust from the Pocahontas Mine, taken from near the place where the explosion originated, but as in the case of the Jackson County coal, flame could not be produced. A dozen trials were made, and though the light in the pipe became greatly lengthened in every experiment, giving off rapid and continuous sparks, in no case did the coal-dust inflame. Common street gas was then mixed with the air in the pipe, there being no fire-damp on hand. After several explosions of air and gas had been caused the amount of gas was reduced in volume just below an explosive compound. When dust from the Pocahontas Mine was added an explosion immediately resulted, and the same result followed when dust from the Jackson county mine was introduced. The Jackson county coal is lower in volatile matter than that of Coshocton county, and ranges high in water, containing from six to eight per cent. The Pocahontas coal, being a semi-bituminous variety, contains less than twenty per cent. of volatile matter.

The results of the experiments made by Prof. Lord are in harmony with those made in England and the Continent. Mr. Gallo-way, the most enthusiastic advocate of the coal-dust theory of explosion, says that the actual chemical composition of the coal from which the dust comes has everything to do with its ability to explode.

While there can be no question that the fine dry coal-dust of many mines is inflammable at ordinary pressure and temperature, when exposed to very strong flames, or that the dust of any bituminous coal may be ignited under especially arranged circumstances, it is still an open question with a vast preponderance of testimony against the claim, whether a mine explosion has ever been traced

to coal-dust alone. Apart from the claim that a blown out shot or a slight explosion of fire-damp is capable of exploding dust raised in the air by disturbance, it is conceded on all hands that the finest, driest and most inflammable dust of mines is incapable of producing explosion under any other conceivable circumstances.

The place to settle this question is in the laboratory of Nature—in the coal mine itself. It would neither be expensive, difficult, nor dangerous to arrange a plan for making all necessary experiments with blown out shots and coal-dust. In fact, an ordinary break-through at the head of any dry room would afford a safe standing place from which to observe the effects of blown out shots in a mine which makes neither fire-damp nor coal-dust. Drill holes could be bored, charged and tamped in the solid face in every manner of actual blasting, which would blow their tamping every time, and coal-dust of every degree of fineness and quality could be scattered along the floor in front of the holes to any desired length and depth.

Until experiments of this kind are made the great majority of practical men will continue to regard it as simply visionary for a blown out shot to explode coal-dust in an atmosphere unmixed with fire-damp, or for pure coal-dust ignited by any means whatever, to carry flame any considerable distance from the origin of the fire.
